```
      IF(IUNIT(6).GT.0) CALL TLK1OT(X(LCRM1),X(LCRM2),
     1     X(LCRM3),X(LCRM4),NM1,NM2,ITLKSV,DELTM1,TLKTIM,IOUT)
```

Normally, the order of call statements in the MAIN program is unimportant for groups of modules performing the same function for different packages. The exception for the TLK1 Package is that the call to the TLK1BD module must precede the call to the BCF1BD module. The reason for this required order is that both budget modules make use of the CV array in calculations of vertical flow to constant-head cells. The TLK1BD module must use the CV array values for the calculations and enter zero values in the array so that incorrect quantities will not be calculated by the BCF1BD module.

Users of the TLK1 Package also should make sure that the BCF1FM module has been modified in accordance with the changes suggested by Hill (1990). If necessary, these changes can be carried out as follows (Hill, 1990, p. 15):

Replace statements in module BCF1FM

```
C7D-----WITH HEAD BELOW TOP ADD CORRECTION TERMS TO RHS AND HCOF.
      RHS(J,I,K)=RHS(J,I,K) + CV(J,I,K-1)*TOP(J,I,KT)
      HCOF(J,I,K)=HCOF(J,I,K) + CV(J,I,K-1)
  220 CONTINUE
```

with statements

```
C7D-----WITH HEAD BELOW TOP ADD CORRECTION TERMS TO RHS AND HCOF.
C7D-----MODIFIED TO PUT CORRECTION COMPLETELY ONTO RIGHT-HAND SIDE
      RHS(J,I,K)=RHS(J,I,K) + CV(J,I,K-1)*(TOP(J,I,KT)-HTMP)
  220 CONTINUE
```

For details on conditions under which these changes are necessary, see section entitled "Corrections for dewatered conditions," page 15.

The MODFLOW program with the modifications and the six modules for the TLK1 Package must be recompiled into a new executable program. The procedure for compiling the program is not addressed in this report.

APPLICABILITY AND LIMITATIONS

The TLK1 Package provides a relatively accurate and efficient way to simulate transient leakage in confining units between model layers. Before the package is applied for simulation of an aquifer system, users need to determine that (1) the capabilities of the TLK1 Package are needed and (2) the package is applicable to the hydrologic conditions being simulated.

The need for the TLK1 Package depends on the type of simulation being carried out. The package is not needed for any steady-state simulations. A common application in which the capabilities of the TLK1 Package is needed is simulation of transient flow in regional or large-scale aquifer systems. One way to assess the need for simulating transient-leakage components for this application is to compare storage coefficients of confining units (product of specific storage and thickness) with storage coefficients of adjacent aquifers. If the storage coefficients of the confining units are much smaller than those of the aquifers, then transient leakage resulting from storage changes in confining units will be much smaller than storage changes in aquifers.

Another potential application of the package is simulation of small-scale systems such as the radius of influence of a pumped well (see section entitled "Problem 2—Simulation of drawdown from pumping in a two-aquifer system," page 28). In these applications, transient-leakage effects are important immediately after a head change in aquifers and the effects diminish after head in the aquifers stabilizes. For example, Hanshaw and Bredehoeft (1968) presented a solution for one-dimensional flow through a confining unit in

response to an instantaneous step change in head, H_0, in one adjacent aquifer and constant head in the other adjacent aquifer. Their solution is given in terms of dimensionless time, which is the product of time since the head change, and γ (equation (8), this report). Most flow from storage in the confining unit occurs between dimensionless-time values of 10^{-2} and 0.5. After a dimensionless time of 0.5, storage change in the confining unit is no longer significant.

Another method of assessing the importance of storage changes in confining units in a ground-water model is to compare results of simulations with and without transient leakage. The storage changes can be judged to be important if the volumes and rates in the budget are not small in relation to the total inflow and outflow rates for the entire model. Similarly, the storage changes are important if their inclusion in a model results in significant changes in computed head or drawdown in the aquifers.

The package is applicable to confining units in which (1) flow is nearly vertical, (2) aquifers are present above and below the confining unit, (3) confining unit properties do not vary vertically, and (4) specific storage of the confining unit is not a function of head. Neuman and Witherspoon (1969) addressed the consequences of the assumption of horizontal flow in aquifers and vertical flow in confining units. They report that errors in direction of flow introduced by the assumption generally are less than 5 percent if the hydraulic conductivities of the aquifers are more than two orders of magnitude greater than that of the confining unit. They indicate that the errors increase with time and decrease with distance from the pumped well.

Item 2 above limits the applicability of the package to the situation in which a confining unit is bounded above and below by aquifers. The TLK1 Package cannot simulate transient leakage in a confining unit that is bounded on the top or bottom by an impermeable boundary. This limitation means that confining units cannot be simulated above the uppermost layer or below the lowermost layer of a ground-water model. Furthermore, if cells above or below a confining unit are inactive, transient-leakage components are not computed. If cells above or below are inactive at the start of a simulation, then no transient-leakage components are computed for the entire simulation. If cells become inactive during the simulation, then transient-leakage components cease when the cells become inactive. An exception to the limitation requiring aquifers above and below each confining unit is the situation in which the confining unit is bounded above by a surface-water body or specified-head source. For that situation, the user could treat all or part of the upper model layer as a specified-head boundary and the TLK1 Package would compute transient leakage between the confining unit and the overlying boundary and between the confining unit and the underlying aquifer.

Leake and Prudic (1991) documented a package for MODFLOW to simulate flow in fine-grained beds in which specific storage is a function of head. Their package is applicable to the situation in which highly compressible interbeds and confining units compact inelastically when sediments are stressed beyond their previous maximum stress. The TLK1 Package cannot be used to simulate flow in confining units in which specific storage is not constant.

The alternative to the TLK1 Package for simulating transient leakage in MODFLOW is the use of model layers to represent the confining unit (McDonald and Harbaugh, 1988, fig. 11). For some problems, that approach might be better than use of TLK1. For example, if horizontal components of flow exist in the confining unit, those components can be simulated by discretizing the confining unit into one or more model layers. Also, use of model layers to simulate confining units might be needed if the model analysis involves particle tracking. The TLK1 Package computes flow rates at the boundaries of confining units but does not compute flow rates within the units. Also, model layers should be used to represent confining units if large areas of adjacent layers are dry or if the water table is within a confining unit.